(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 066 846 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.01.2001 Bulletin 2001/02

(51) Int Cl.[7]: **A61M 5/145**, A61M 5/168

(21) Application number: **00305086.1**

(22) Date of filing: **15.06.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **03.07.1999 GB 9915525**

(71) Applicant: **Smiths Industries Public Limited Company**
London, NW11 8DS (GB)

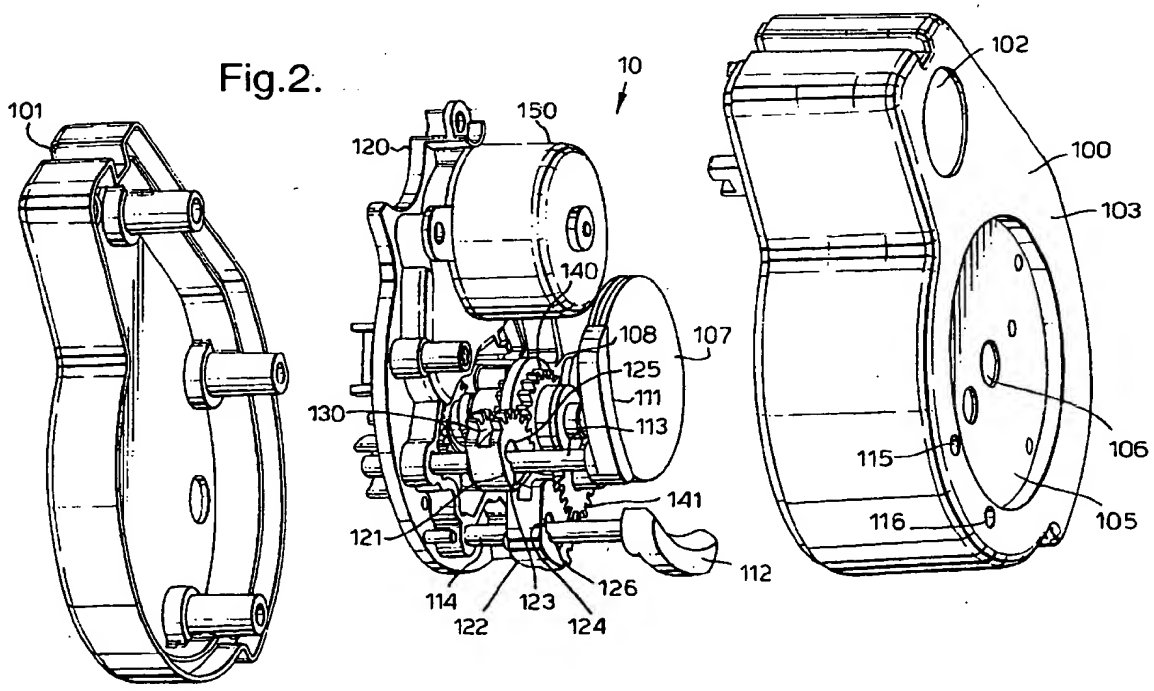
(72) Inventor: **Ford, Andrew John**
Great Glen, Leicestershire LE8 9EA (GB)

(74) Representative: **Flint, Jonathan McNeill et al**
765 Finchley Road
London NW11 8DS (GB)

(54) Syringe pumps

(57) Syringe pump has plunger head retainer (10) with two retainer arms (111 and 112) mounted on shafts (113 and 114) extending parallel to the syringe axis. Each shaft carries gear (121 and 122), which is engaged by common gear wheel (142) mounted on threaded shaft (146). After the syringe (3) has been loaded in the pump, the plunger head retainer (10) is driven forwards until a pad (107) coupled with a force sensor (108) detects contact with the head (36). This causes the retainer arms to be swung in across the forward side of the plunger head (36) and to be pulled rearwardly against the plunger head. The pump then reduces the force applied by the retainer arms to ensure that the force sensor (108) can respond to force on the plunger (35) during expulsion of liquid from the syringe.

Fig.2.



EP 1 066 846 A1

Description

[0001] This invention relates to syringe pumps of the kind adapted to receive a syringe of the kind having a plunger movable along a barrel, the pump including a plunger head retainer mechanism having a forwardly-facing surface adapted to engage a rear surface of the plunger head and to apply a forwardly-directed force to the plunger.

[0002] Syringe pumps are used to supply medication to a patient from a pre-filled syringe via an infusion line. The syringe pump applies a force to the plunger of the syringe to drive medication into the infusion line at a controlled rate. The head of the plunger is retained in such a way as to allow the plunger to be pushed in but to prevent the plunger moving in of its own accord as a result of siphoning of fluid from the syringe barrel. The plunger head is usually retained by means of wedge-like arms that move across the forward surface of the head and force the rear surface of the plunger head against a forward facing surface on the plunger head retainer so as to clamp it firmly against this surface. Because the size and thickness of plunger heads vary in different syringes, the plunger head retainer may not be able to accommodate all the different heads, thereby restricting the range of syringes with which the pump can be used. If the plunger head retainer does not retain the plunger head securely, it may allow the plunger to move and allow fluid to siphon from the syringe.

[0003] It is common to measure the force exerted on the plunger head by the pump driver in order to be able to detect excess force, such as caused by an occlusion. It is an advantage to be able to respond to a low level of excess force without false alarms. The force sensor is, however, usually located relatively remotely of the plunger head so a margin must be allowed for friction and other forces acting on the drive train.

[0004] It is an object of the present invention to provide an alternative syringe pump and method of operation.

[0005] According to one aspect of the present invention there is provided a syringe pump of the above-specified kind, characterised in that the plunger head retainer mechanism includes a force sensor responsive to force exerted on the plunger head by the retainer mechanism during displacement of the plunger.

[0006] The retainer mechanism preferably includes a pad coupled with the mechanism via the force sensor such that the forwardly-directed force is applied to the plunger via the pad. The retainer mechanism may include a spring arranged to urge the pad forwardly. The retainer mechanism is preferably arranged initially to pull the plunger head rearwardly relative to the mechanism, thereby increasing force on the sensor, and is preferably arranged subsequently to relieve the force on the sensor.

[0007] According to another aspect of the present invention there is provided a syringe pump of the above-specified kind, characterised in that the retainer mechanism has at least one retainer member that is movable both laterally and axially so that it can be displaced laterally across the front surface of the plunger head and can be displaced axially rearwardly against the front surface of the plunger head.

[0008] Preferably the retainer mechanism is operable such that the or each retainer member is initially displaced axially rearwardly relative to the mechanism to apply force between the rear surface of the plunger head and the forwardly-facing surface and is subsequently displaced axially forwardly a small distance to reduce the force. The or each retainer member may include an arm extending from a shaft, the shaft extending parallel with the axis of the syringe, such that the arm can be displaced laterally by rotating it about the shaft and such that the or each arm can be displaced axially by moving the shaft along its axis. The or each shaft is preferably driven by a gear assembly including a rotatable, threaded shaft and a gear wheel threaded on the shaft such that rotation of the shaft initially moves the gear wheel along the shaft to the end of the shaft and thereafter continued rotation of the shaft rotates the gear wheel.

[0009] According to further aspect of the present invention there is provided a method of operating a syringe pump comprising the steps of: locating a syringe on the pump with a plunger head retainer in a rear position; displacing the plunger head retainer forwardly until it contacts the rear surface of the plunger head; retaining the plunger head with the plunger head retainer such as to prevent forward displacement of the plunger head relative to the retainer but to allow continued monitoring of force applied between the plunger head and the retainer; and advancing the retainer to move the plunger forwards and dispense contents of the syringe whilst monitoring the force between the plunger head retainer and the plunger head.

[0010] A syringe pump and its method of operation, according to the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a simplified view of the front of the pump;

Figure 2 is a perspective, exploded view of the plunger head retainer mechanism of the pump from below;

Figure 3 is a perspective, exploded view of the plunger head retainer mechanism of the pump from the rear side; and

Figure 4 is an enlarged perspective view of a subassembly within the retainer mechanism.

[0011] With reference first to Figure 1, the pump includes an outer housing 1 with a recess 2 on its front surface shaped to receive a syringe 3 of conventional

kind. The syringe 3 has a cylindrical barrel 30 with an outlet or nose 31 at its forward end and a flange or ear 32 at its rear end. The nose 31 is connected to an infusion line 5 so that a medication liquid in the syringe can be dispensed to a patient via the infusion line, by pushing in the plunger 35 of the syringe. The pump has a conventional drive mechanism 7, such as including a lead screw 8 driven by a motor 9, coupled with a novel retainer mechanism 10 for engaging the head 36 of the plunger 35. The motor 9 is driven by a control unit 11, which receives inputs from a keypad 12, or other user input means, and various sensors. The control unit 11 also provides an output to a display 13.

[0012] With reference now also to Figures 2 and 3, the plunger head retainer mechanism 10 has an outer casing provided by a forward part 100 and a rear part 101. The forward part 100 has a circular hole 102 on its outer face 103 towards its edge, in which is received a tubular sleeve 104 extending parallel with the syringe 3. The sleeve 104 is mounted axially about the leadscrew 8 so that rotation of the leadscrew displaces the sleeve and retainer mechanism 10 axially forwards or backwards.

[0013] The front face 103 of the casing also has a larger, shallow, circular recess 105 with a central aperture 106. In the recess 105 is located a circular pad 107 having a rearwardly-extending force sensor in the form of a strain beam 108 projecting through the aperture 106 inside the casing. For clarity, Figures 2 and 3 show the pad 107 mounted on the internal components of the mechanism 10 although, in practice, it is located on the external surface of the forward casing part 100. The pad 107 is resiliently urged axially outwardly by a coil spring 109 around the strain beam 108. The strain beam 108 provides an output to the control unit 11 representative of axial pressure on the pad 107.

[0014] Two arms 111 and 112 extend parallel with the front face 103 and are spaced a short distance forwardly of the face. The arms 111 and 112 are curved along their length along an arc generally coaxial, in their rest position, with the pad 107. The arms 111 and 112 are mounted on respective shafts 113 and 114 extending parallel to the axis of the syringe 3 and projecting through bushes 115 and 116 in the front face 103 of the casing, towards one edge. The rear ends of the shafts 113 and 114 are journalled with a base plate 120 extending laterally within the retainer mechanism 10. The shafts 113 and 114 are movable axially along their length as well as being able to rotate about their axes. Each shaft 113 and 114 carries a segment gear 121 and 122 mounted on the shafts by means of a hole with a butterfly-shape slot 123 and 124 in the gears. The shafts 113 and 114 each carry two radially-extending pins 125 and 126 located in the slots 123 and 124 so that the gears 121 and 122 are rotatable relative to the shafts through a small angle, as limited by the engagement of the pins with the opposite sides of the slots. A clip 127 is secured to each shaft on one side of the gears to prevent axial movement of the gears in one direction along the shafts - movement in the other direction being prevented by the pins 125 and 126. A spring (not shown) is secured to the clip 127 on each shaft 113 and 114 to apply a resilient force urging one shaft 113 to rotate in a clockwise sense relative to the front face 103 of the casing and urging the other shaft 114 in the opposite sense. Thus, the springs urge the arms 111 and 112 to swing inwardly towards one another.

[0015] The segment gears 121 and 122 each have a channel 130 around the toothed edge of the gear dividing into two parallel spaced segments. One segment gear 121 is engaged directly by a central gear sub-assembly 140, whereas the other gear 122 is engaged by an idler gear 141 driven from the central gear assembly. The central gear sub-assembly 140 is shown most clearly in Figure 4. The gear sub-assembly has a circular gear wheel 142 with a flange 143 projecting radially midway along its length. The flange 143 is shaped to fit within the channel 130 in the segment gear 121. The gear wheel 142 is fixed on a boss 144 having a helical thread 145 of square profile around its inner surface. The central gear sub-assembly 140 also includes a hollow shaft 146 with a helical thread on its outer surface, which matches and engages the thread 145 on the inside of the boss 144. At its rear end, the shaft 146 has a spur gear 147, the spur gear and shaft being free to rotate on an internal spindle 148 having a flange 149 at its forward end. The central gear sub-assembly 140 is mounted on the base plate 120 with the shaft 146 extending parallel to the syringe axis. The spur gear 147 engages a gear train coupled with an electric motor 150 within the plunger head retainer mechanism 10. It can be seen that rotation of the spur gear 147 would cause movement of the gear wheel 142 along the threaded shaft 146 if rotation of the gear wheel were prevented, the extent of displacement being limited by the length of the shaft. The retainer mechanism 10 also includes a sensor (not shown) responsive to the angular position of the arms 111 and 112, or the shafts 113 and 114, and located to sense when the arms have moved to their extreme outward position.

[0016] Initially, the motor 150 is rotated forwardly to rotate the spur gear 147 and the threaded shaft 146 clockwise and thereby jack the gear wheel 142 forwardly along the shaft. This forward movement of the gear wheel 142 also moves the segment gears 123 and 124 forwardly and hence moves the arms 111 and 112 forwardly. When the gear wheel 142 reaches its maximum extent of movement along the threaded shaft 146, as limited by engagement with the flange 149, continued rotation of the shaft causes the gear wheel to rotate clockwise. This in turn causes the idler gear 141 to rotate anticlockwise so that the segment gears 121 and 122 are rotated anticlockwise and clockwise respectively, which thereby swings the arms 111 and 112 open. The arms 111 and 112 swing open until the arm position sensor detects they are at their fully open, at which time the

control unit 11 stops driving the motor 150 forwardly.

[0017] The retainer mechanism 10 is now ready to receive the syringe plunger head 36. The syringe 3 is loaded in the pump and the motor 9 is powered to rotate the leadscrew 8 relatively rapidly, so as to drive the plunger head retainer mechanism 10 forwardly until the pad 107 contacts the rear surface of the plunger head 36. Initial contact is sensed by an optical detector (not shown), which, when tripped, slows forward movement of the retainer mechanism 10 until the strain beam registers a small strain. This causes the control unit 11 to stop further rotation of the leadscrew 8 and causes the motor 150 in the plunger head retainer mechanism 10 to be powered in the reverse direction. This rotates the threaded shaft 146 in an anticlockwise sense so that the gear wheel 142 is also rotated anticlockwise, which in turn rotates the idler gear 141 clockwise. The anticlockwise rotation of the gear wheel 142 and the clockwise rotation of the idler gear 141 cause the segment gears 121 and 122 to rotate clockwise and anticlockwise respectively. The spring force causes the arms 111 and 112 to swing in together to a closed position. The arms 111 and 112 swing together until they contact the shaft of the plunger 35, which prevents further rotation of the arms. The slots 123 and 124 in the segment gears 121 and 122 allow them to rotate further through a few degrees until a part of the gear wheel contacts a stop on the forward part 100 of the casing, thereby preventing further rotation of the central gear wheel. The slots 123 and 124 in the segment gears enable the arms 111 and 112 to stop in a partially closed position (limited by engagement with the plunger shaft) whilst ensuring that they are swung back to the fully open position when the motor direction is reversed.

[0018] Continued rotation of the threaded shaft 146 by the motor 150 causes the gear wheel 142 to be pulled down the shaft, the arms 111 and 112 also being pulled down because of the engagement of the flanges 143 in the channels 130 of the segment gears 121 and 122. The arms 111 and 112 are, therefore, pulled rearwardly until they engage the forward surface of the plunger head 36. When this happens, the plunger head 36 is pulled rearwardly relative to the retainer mechanism 10, against the forward surface of the pad 107 causing an increase in pressure on the strain beam 108. When this increase in pressure is sensed, the pump control unit 11 stops the motor 150 and reverses it a few steps to give a predetermined clearance between the rear surface of the pad 107 and the floor of the recess 105. The leadscrew 8 is then rotated in the normal way to move the retainer mechanism 10, and hence the plunger 35, forwardly to dispense the contents of the syringe 3 at the required rate.

[0019] Because the plunger head 36 is coupled with the retainer mechanism 10 via the pad 107 and the strain beam 108, and because there is a clearance between the rear surface of the pad and the floor of the recess 105, the strain beam is responsive to pressure exerted by the retainer mechanism on the plunger 35 while the plunger is actually being displaced to expel medication from the syringe 3. If there should be an occlusion in the infusion line 5, or if the syringe 5 should jam, there would be an immediate increase in pressure on the strain gauge 110. Because the arrangement of the present invention enables pressure on the plunger to be measured directly, the apparatus can be sensitive to small increases in pressure.

[0020] The plunger head retainer mechanism can be used with a wide variety of plunger heads because the action of spacing the retainer arms and subsequently pulling them back to clamp the head allows for wide variation in the size and shape of head.

Claims

1. A syringe pump adapted to receive a syringe (3) of the kind having a plunger (35) movable along a barrel (30), the pump including a plunger head retainer mechanism (10) having a forwardly-facing surface (107) adapted to engage a rear surface of the plunger head (36) and to apply a forwardly-directed force to the plunger, characterised in that the plunger head retainer mechanism (10) includes a force sensor (108) responsive to force exerted on the plunger head (36) by the retainer mechanism (10) during displacement of the plunger (35).

2. A syringe pump according to Claim 1, characterised in that the retainer mechanism (10) includes a pad (107) coupled with the mechanism via the force sensor (108) such that the forwardly-directed force is applied to the plunger (35) via the pad.

3. A syringe pump according to Claim 2, characterised in that the retainer mechanism (10) includes a spring (109) arranged to urge the pad (107) forwardly.

4. A syringe pump according to any one of the preceding claims, characterised in that the retainer mechanism (10) is arranged initially to pull the plunger head (36) rearwardly relative to the mechanism (10), thereby increasing force on the sensor (108), and is arranged subsequently to relieve the force on the sensor.

5. A syringe pump adapted to receive a syringe (3) of the kind having a plunger (35) movable along a barrel (30), the pump including a plunger head retainer mechanism (10) having a forwardly-facing surface (107) adapted to engage a rear surface of the plunger head (36) and to apply a forwardly-directed force to the plunger, characterised in that the retainer mechanism (10) has at least one retainer member (111 and 112) that is movable both laterally and ax-

ially so that it can be displaced laterally across the front surface of the plunger head (36) and can be displaced axially rearwardly against the front surface of the plunger head.

6. A syringe pump according to Claim 5, characterised in that the retainer mechanism (10) is operable such that the or each retainer member (111, 112) is initially displaced axially rearwardly relative to the mechanism (10) to apply force between the rear surface of the plunger head (36) and the forwardly-facing surface (107) and is subsequently displaced axially forwardly a small distance to reduce the force.

7. A syringe pump according to Claim 5 or 6, characterised in that the or each retainer member includes an arm (111, 112) extending from a shaft (113, 114) and that the shaft extends parallel with the axis of the syringe (3), such that the arm can be displaced laterally by rotating it about the shaft.

8. A syringe pump according to Claim 7, characterised in that the or each arm (111, 112) is displaced axially by moving the or each shaft (113, 114) along its axis.

9. A syringe pump according to Claim 7 or 8, characterised in that the or each shaft (113, 114) is driven by a gear assembly (140) including a rotatable, threaded shaft (146) and a gear wheel (142) threaded on the shaft such that rotation of the shaft initially moves the gear wheel along the shaft to the end of the shaft and thereafter continued rotation of the shaft rotates the gear wheel.

10. A method of operating a syringe pump comprising the steps of: locating a syringe (3) on the pump with a plunger head retainer (10) in a rear position; displacing the plunger head retainer forwardly until it contacts the rear surface of the plunger head (36); retaining the plunger head with the plunger head retainer such as to prevent forward displacement of the plunger head (36) relative to the retainer but to allow continued monitoring of force applied between the plunger head and the retainer; and advancing the retainer (10) to move the plunger (35) forwards and dispense contents of the syringe whilst monitoring the force between the plunger head retainer and the plunger head (36).

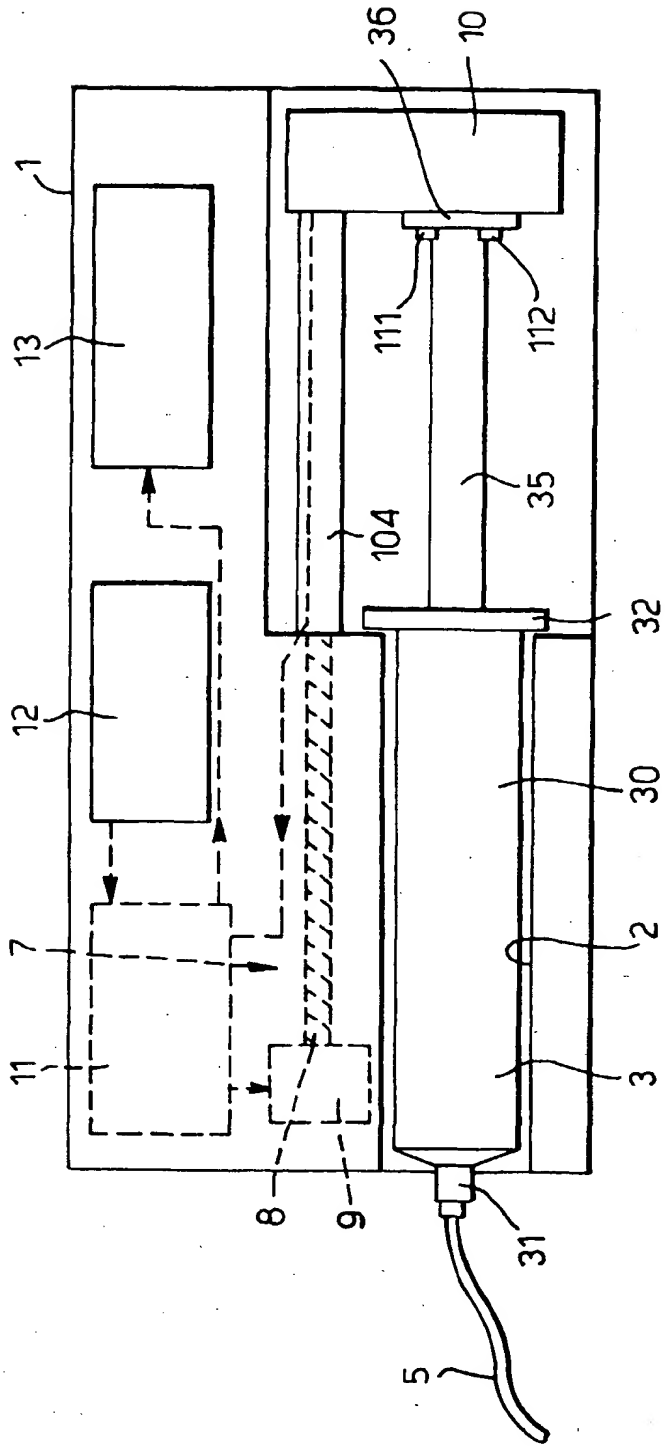


Fig.1.

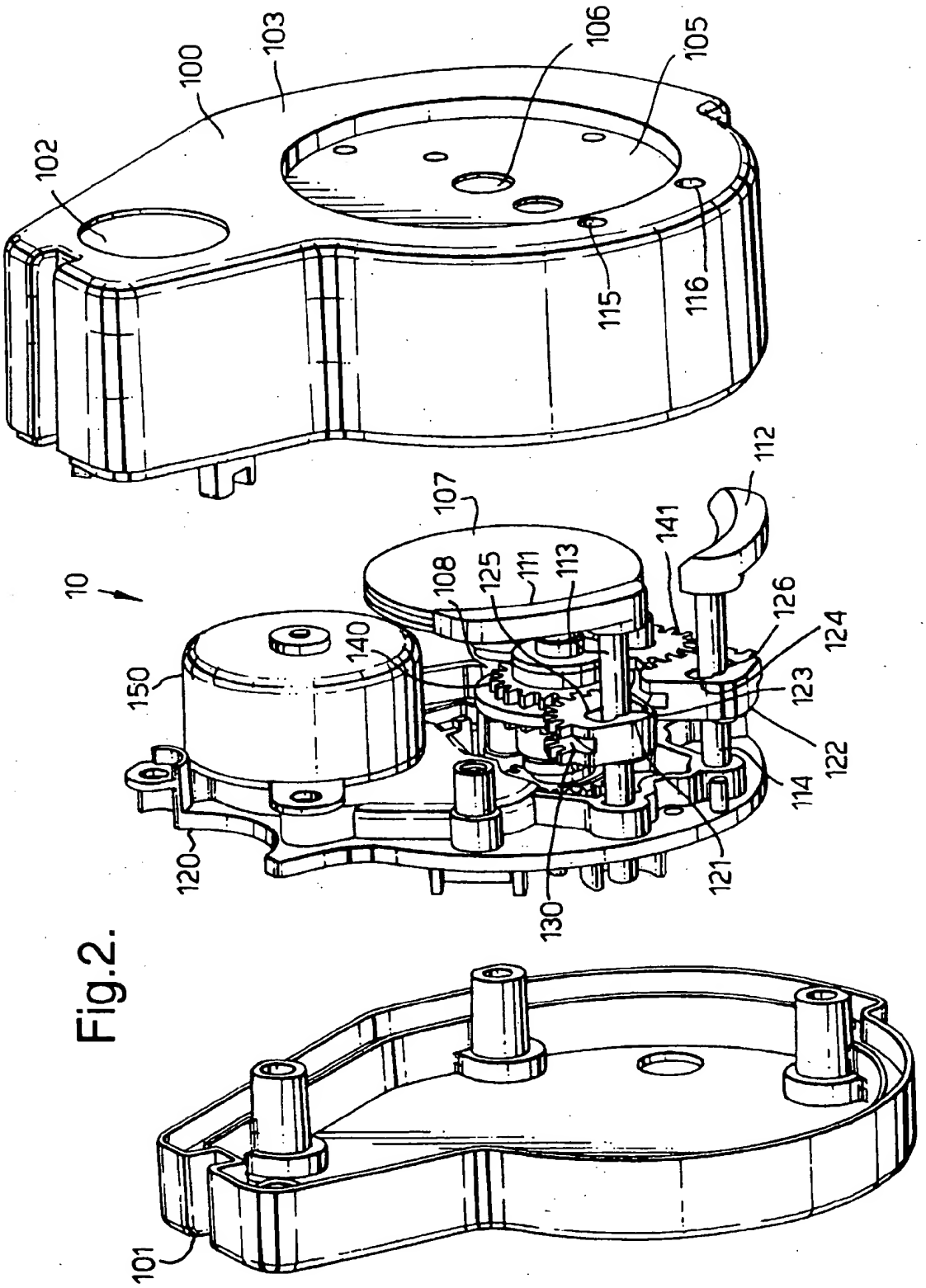


Fig.2.

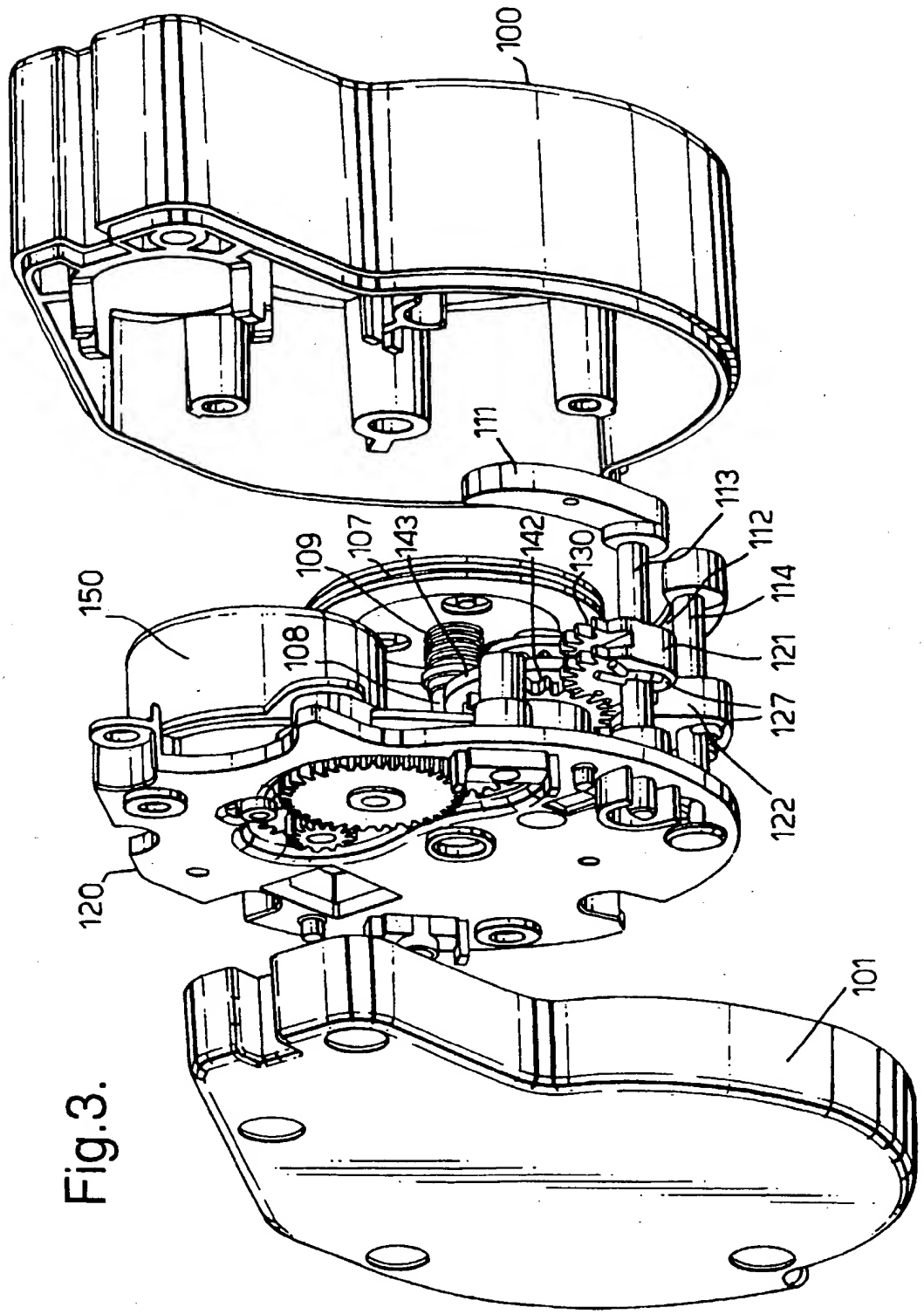


Fig.3.

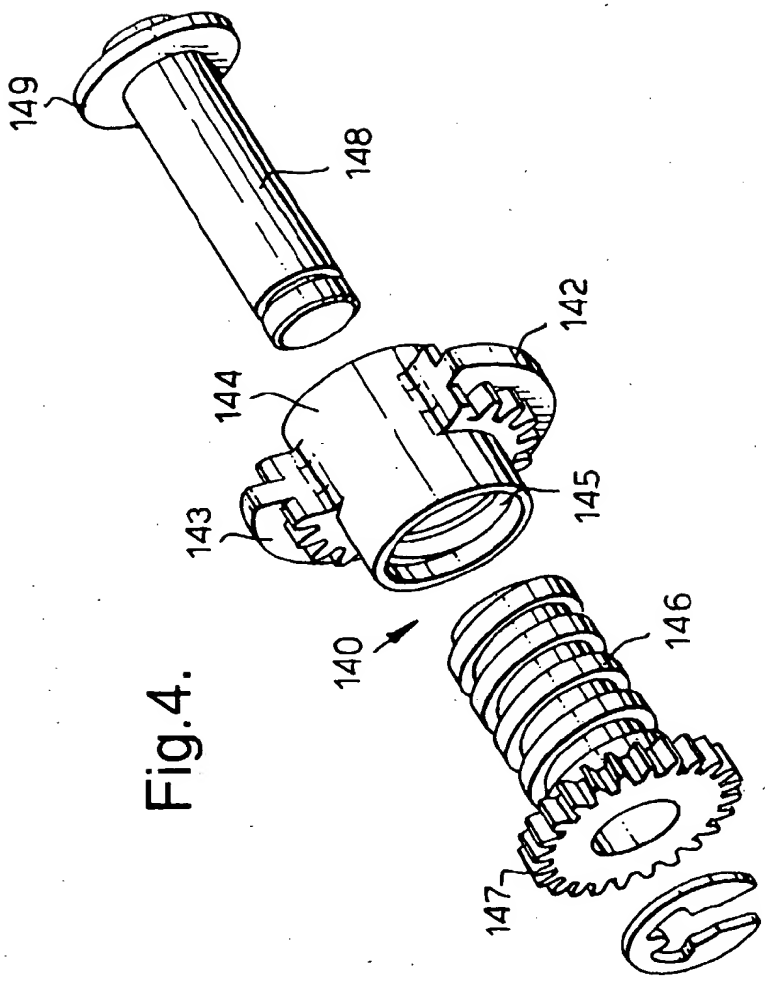


Fig.4.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 5086

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 879 360 A (CRANKSHAW DAVID PILKINGTON) 9 March 1999 (1999-03-09)	1-3	A61M5/145 A61M5/168
A	* the whole document *	5,10	
X	US 5 501 665 A (JHUBOO ABDEL-NASSER ET AL) 26 March 1996 (1996-03-26)	1,2	
A	* the whole document *	5,10	
X	US 5 814 015 A (COWEN BARRY ET AL) 29 September 1998 (1998-09-29)	1	
A	* column 8, line 54 - column 9, line 37; figures 7-9 *	5,10	
X	US 5 647 853 A (HENNING CRAIG M ET AL) 15 July 1997 (1997-07-15) * the whole document *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

A61M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	4 October 2000	Jameson, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 5086

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-10-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5879360 A	09-03-1999	AU 690631 B	30-04-1998
		AU 1528195 A	08-08-1995
		WO 9520145 A	27-07-1995
		GB 2300926 A,B	20-11-1996
US 5501665 A	26-03-1996	FR 2710537 A	07-04-1995
		EP 0646382 A	05-04-1995
US 5814015 A	29-09-1998	AU 708108 B	29-07-1999
		AU 4982096 A	11-09-1996
		EP 0813428 A	29-12-1997
		JP 11500643 T	19-01-1999
		WO 9625963 A	29-08-1996
US 5647853 A	15-07-1997	CA 2187094 A	12-09-1996
		EP 0758253 A	19-02-1997
		JP 9512472 T	16-12-1997
		WO 9627398 A	12-09-1996

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82